REMARKS

Applicants have amended their claims in order to further clarify the definition of the present invention. Specifically, claims 1, 2, 4, 6, 9 and 27 have been amended to recite that the neighboring film " includes" a material selected from a specified group; and claim 4 has been amended in light of objections thereto, in Item 2 on page 2 of the Office Action mailed July 6, 2001. In light of these amendments to claim 4, it is respectfully submitted that the required corrections to claim 4 have been made. Moreover, in light of the indication by the Examiner in Item 8 on page 6 of the Office Action mailed July 6, 2001, it is respectfully submitted that claim 4 should now be allowed. Noting the reasons for allowance set forth in Item 9 on page 6 of the Office Action mailed July 6, 2001, it is respectfully submitted that allowance of previously considered claims should be maintained notwithstanding amendments thereto.

The Examiner is thanked for the indicated allowance of claims 1, 2, 5, 6, 9-20, 22-25 and 27-29. Moreover, as indicated previously, claim 4 should also now be allowed.

Applicants have added new claims 32-37 to the application. Claims 32-34 correspond respectively to claims 3 (Amended), 30 and 31, but additionally recite that the neighboring film is provided so as to restrain formation of voids due to electromigration of copper of the copper film (or restrain formation of voids due to electromigration of copper or platinum of the respective copper or

platinum film). Noting, for example, the statement by the Examiner in Item 9 on page 6 of the Office Action mailed July 6, 2001, that the prior art of record does not teach or suggest that neighboring layers of rhodium, ruthenium, iridium, osmium or platinum prevent the formation of voids due to the electromigration of copper, it is respectfully submitted that newly submitted claims 32-34 should be allowed.

Claims 35-37 define a semiconductor device having layered interconnection structure, which includes a copper (or copper or platinum) film and a neighboring film. Material of the neighboring film, and locations of the copper (or copper or platinum) film and neighboring film are defined. In addition, claims 35 and 37 recite that the neighboring film substantially prevents voids due to electromigration; in view thereof, claims 35 and 37 should clearly be allowable.

Applicants respectfully traverse the rejection of claims 3, 30 and 31 on prior art grounds, and respectively submit that all claims now in the application and being considered on the merits therein, patentably distinguish over the teachings of the references applied in the Office Action mailed July 6, 2001, that is, the U.S. patents to Schacham-Diamand, et al., No. 5,824,599, and to Hussein, et al., No. 6,020,266, and the article entitled "Diffusion Barrier Between Copper and Silicon", in IBM Technical Disclosure Bulletin, vol. 35, no. 1B (June 1992), pages 214 and 215, under the provisions of 35 USC 102 and 35 USC 103.

It is respectfully submitted that the teachings of these applied references would have neither disclosed nor would have suggested a semiconductor device as in claim 3, including, inter alia, wherein the neighboring film is formed of ruthenium as the primary constituent element, in the semiconductor device with a multilayered structure including a copper film interconnect formed on one primary surface of a semiconductor substrate, the interconnect having a multilayered structure including a copper film formed through sputtering and a copper film formed through plating or chemical vapor deposition. See claim 3.

In addition, it is respectfully submitted that the applied references would have neither taught nor would have suggested such semiconductor device as in the present claims, having the layered interconnection structure including a copper film (see claim 30) or a copper or platinum film (see claim 31), with the layered interconnection structure including this copper film (or copper or platinum film) and a neighboring film, this neighboring film having as the primary constituent element an element selected from a first group consisting of rhodium, ruthenium, iridium, osmium and platinum when the interconnection structure includes a copper film, and having as the primary constituent element an element selected from a second group consisting of rhodium, ruthenium, iridium and osmium when the interconnection structure includes a platinum film, at least one of the copper or platinum film, and neighboring film, being a film made by physical vapor deposition. Note claims 30, 31 and 36.

The present invention is directed to a semiconductor device having a layered (for example, multilayered) interconnect structure. In recent large-scale-integrated semiconductor devices, copper interconnects are being employed since they have a lower electrical resistance than conventional aluminum interconnects. However, diffusion of copper in semiconductor devices degrades characteristics of such devices; and, accordingly, diffusion barriers of, for example, titanium nitride, tungsten or tantalum have been used.

However, in large-scale-integrated semiconductor devices with fine patterns, in which high-density current occurs, electromigration (in which atoms are diffused owing to electron streams flowing in the fine patterns and due to heat generated by the flow of electrons) is a problem, causing voids and interconnect breakdowns. Use of a diffusion barrier of, e.g., titanium nitride, does not provide satisfactory electromigration resistance.

Against this background, Applicants have clarified a source of the electromigration problem, and having clarified such source, have found a technique which overcomes the problem of voids due to electromigration and the resulting interconnect breakdown. Applicants have clarified that, in a layered interconnect structure using, for example, a titanium nitride film as a diffusion barrier kept in contact with the copper film, the significant difference between the material of the diffusion barrier and copper in the length of the sides of the unit cell brings about a disordered atomic configuration at the interface

therebetween, thereby promoting copper diffusion that results in the problem of voids and interconnect breakdowns. Having clarified this problem, and in order to prevent the voids and breakdowns in copper interconnects, Applicants utilize materials that differ little from copper in a length of the sides of the unit cell. See the paragraph bridging pages 2 and 3 of Applicants' specification. Applicants have further found that where the difference between sides of the rectangular unit cells representing the copper and neighboring films is less than 13%, the aforementioned problems in voids and interconnect breakdowns are avoided.

In addition, Applicants have found specific materials, and also specific techniques for forming the various layers, whereby the aforementioned differential in lengths of sides of the units cells are sufficiently small, so as to avoid the voids and interconnect breakdowns. That is, Applicants have found that by forming at least one of the adjacent layers of copper and neighboring film by physical vapor deposition,, with selection of material of the neighboring film, the aforementioned problem of voids can be avoided, due to the structure formed.

Attention is respectfully directed to Figs. 2-5 of Applicants' original disclosure, together with the description on pages 13-16 of Applicants' specification. This shows that the diffusion coefficient of the copper film greatly increases in regions where there is a great size differential. It is respectfully

submitted that this evidence in Applicants' specification must be considered, in determining the question of unobviousness. See In re DeBlauwe, 222 USPQ 191 (CAFC 1984). It is respectfully submitted that this evidence shows unexpectedly lower diffusion occurs in connection with copper or platinum, on the one hand, and the various materials within the present claims, including ruthenium, on the other, where the difference in unit cell length is relatively small. This evidence shows unexpectedly better results achieved according to the present invention, and clearly establishes unobviousness of the present invention.

Schacham-Diamand, et al. discloses a technique for fabricating copper interconnects by electroless metallization, employing a copper catalytic layer to initiate the autocatalytic process of electroless deposition, and the use of a protective layer to protect the catalytic surface until the wafer is subjected to the electroless deposition technique. Note column 2, lines 50-56. Note also from column 6, line 13 to column 7, line 44. This patent discloses use of an adhesion promoter layer 16, a barrier layer 17 and a catalytic seed layer 18, this patent disclosing that the catalytic seed layer 18 can be of copper or comprised of nickel, cobalt, silver, gold, palladium, platinum or rhodium with copper. See column 7, lines 22-30.

It is emphasized that Schacham-Diamand, et al. utilizes a catalytic layer 18 including nickel, cobalt, silver, gold, palladium, platinum and/or rhodium,

along with copper. Note particularly column 7, lines 22-31, especially lines 28-31. Schacham-Diamand, et al. discloses electroless copper deposition performed in a copper solution, with the aluminum layer 19, as well as the underlying alloy layer at the catalytic seed layer 18/protective layer 19 interface, dissolving when subjected to the electroless deposition bath, thereby exposing the underlying catalytic layer 18 for the electroless deposition of copper to occur. This patent discloses that the dissolving of aluminum layer 19 allows copper to be deposited on a non-contaminated and non-oxidized copper surface of catalytic layer 18. Note especially column 7, lines 36-44.

Noting particularly that this patent discloses a non-contaminated and non-oxidized copper surface of catalytic layer 18, it is respectfully submitted that the teachings of Schacham-Diamand, et al. would have taught away from the subject matter of claims 30, 31 and 36, wherein the device has the neighboring film having, as the primary constituent element thereof, an element selected from the specified group. That is, Schacham-Diamand, et al. requires dissolving of the aluminum protective layer 19, including alloys of aluminum with, e.g., rhodium, with copper deposited on an non-contaminated and non-oxidized copper surface of catalytic layer 18. This would have taught away from the catalytic layer 18 having an element of the recited elements as the primary constituent element of a layer adjacent the copper layer.

Again, it is emphasized that the present invention is directed to a semiconductor device having specific layers, including a neighboring film adjacent the copper (or copper or platinum) film. The dissolving of the aluminum together with the alloying materials from the catalytic layer would have taught away from structure in the device wherein a film formed of the listed element as the primary constituent element is adjacent the copper (or copper or platinum) film.

The contention by the Examiner that Schacham-Diamand, et al. clearly indicates "that platinum or rhodium as well as other metals can be used as an alternative material for the copper seed layer", and that in such alternative embodiments "the platinum or the rhodium would be the sole constituent" (emphasis in original), is respectfully traversed. It is respectfully submitted that Schacham-Diamand, et al. discloses that the catalytic layer includes one of the specified elements along with the previously mentioned copper, and does not disclose, nor would have suggested, a catalytic seed layer where platinum or rhodium would be the sole constituent. See column 7, lines 22-34 of Schacham-Diamand, et al. Moreover, it is again emphasized that according to Schacham-Diamand, et al., elements such as rhodium in the seed layer form alloys with the aluminum protective layer 19, and with dissolving of the layer 19 the additional elements such as rhodium would be removed from the semiconductor device. For this reason also, it is respectfully submitted that Schacham-Diamand, et al.

would have neither taught nor would have suggested, and in fact would have taught away from, the presently claimed device, including the neighboring film having one of the specified elements as the primary constituent element.

Thus, as is clear from the foregoing, it is respectfully submitted that Schacham-Diamand, et al. would have neither taught nor would have suggested the presently claimed subject matter, including the neighboring film having the specified element as the primary constituent element thereof.

Furthermore, it is respectfully submitted that Schacham-Diamand, et al., disclosing use of the various listed metals with copper, does not include ruthenium among the listed elements; and, moreover, this patent does not describe that the catalytic seed layer provides electromigration resistance. It is respectfully submitted that Schacham-Diamand, et al. would have neither taught nor would have suggested the presently claimed invention, or advantages achieved thereby.

It is respectfully submitted that the combined teachings of Hussein, et al. and the IBM Technical Disclosure Bulletin would have neither disclosed nor would have suggested the semiconductor device as in claim 3, including wherein the neighboring film is formed of ruthenium as the primary constituent element, and is formed through sputtering; and wherein the copper film interconnect has a multilayered structure including a copper film formed through sputtering and a copper film formed through plating or chemical vapor deposition.

Hussein, et al. discloses fabrication of via plugs and metal lines in interconnect systems, including a barrier layer formed onto a substrate surface that has at least one via, and a conductive layer formed on the barrier layer. This patent discloses that appropriate conductive material for the barrier layer may be titanium nitride or tantalum.

The IBM Technical Disclosure Bulletin article discloses a diffusion barrier between copper and silicon, and describes that the diffusion barrier should be a material that does not interact with silicon and into which copper does not diffuse until at least 500°C. This article goes on to state that materials having large values of elastic constants C_{11}, C_{12} and C_{44} can form barriers to diffusion of copper into silicon, and that the metal that ideally fulfills these criteria is rhenium; and that similar desirable values, of elastic constants and eutectic temperatures, are a property of osmium, ruthenium and iridium.

It is respectfully submitted that Hussein, et al. discloses a barrier layer 5 to prevent copper diffusion into the dielectric layer 3 (SiO_2) in the integrated circuit device. The article in the IBM Technical Disclosure Bulletin, on the other hand, discloses various materials to prevent copper diffusion into silicon. Since silicon (a semiconductor) has different characteristics from silicon oxide (a dielectric), it is respectfully submitted that one of ordinary skill in the art concerned with in Hussein, et al., concerned with preventing copper diffusion into the dielectric layer, would not have looked to the teachings of the article from IBM Technical

Disclosure Bulletin. For example, although rhenium prevents copper diffusion into silicon, in the copper/rhenium/silicon structure in the aforementioned article, it does not satisfactorily prevent copper diffusion into, for example, silicon oxide-containing materials. In addition, rhenium is not as good for preventing electromigration, as described in the article. Therefore, it is respectfully submitted that the teachings of the aforementioned article would have neither disclosed nor would have suggested materials to use with oxidized silicon; and there would have been no suggestion, even from the combined teachings of Hussein, et al. and the aforementioned article, to use materials described in the article as a substitute for materials in Hussein, et al.

Moreover, it is respectfully submitted that there would have been no motivation for combining the teachings of Hussein, et al. and the aforementioned article, as applied by the Examiner. Without such motivation, clearly the combination of teachings of references as applied by the Examiner is improper under 35 USC 103.

In any event, noting the unexpectedly better results achieved according to the present invention as described in Applicants' original disclosure and discussed previously, even assuming, arguendo, that the teachings of Hussein, et al. and the aforementioned article would have established a prima facie case of obviousness such prima facie case is clearly overcome by the evidence of record,

in connection with unexpectedly better results achieved when the neighboring film is formed of ruthenium.

The comments by the Examiner that the article from the IBM Technical Disclosure Bulletin notes that ruthenium is an excellent barrier against diffusion of copper and its alloys, is noted. It is respectfully submitted, however, that this article is primarily directed to rhenium, not ruthenium, as a diffusion barrier, and is solely directed to the various specified materials as diffusion barriers between copper and silicon. On the other hand, Hussein, et al. discloses a barrier layer on an underlying and adjacent dielectric layer. Taking the teachings of the applied references as a whole, including that Hussein, et al. discloses a barrier layer on a dielectric and that the article is concerned with a barrier between copper and silicon, it is respectfully submitted that one of ordinary skill in the art concerned with in Hussein, et al. would not have looked to the teachings of this IBM Technical Disclosure Bulletin article for a substitution of materials.

The contention by the Examiner that the first sentence of the final paragraph of the aforementioned article clearly indicates that "ruthenium" is an excellent barrier against the diffusion of copper and its alloys, is respectfully traversed. First of all, this first sentence of the last paragraph indicates that rhenium, not ruthenium, is a diffusion barrier, and this article as a whole indicates that rhenium is a diffusion barrier between copper and silicon. Thus, one of ordinary skill in the art concerned with in Hussein, et al., concerned with

a barrier layer adjacent the dielectric, would not have looked to the aforementioned article.

In view of the foregoing comments and amendments to the claims, reconsideration and allowance of all claims remaining in the application are respectfully requested.

Attached hereto is a marked-up version of the changes made in the claims by the current Amendment. This marked-up version is on the attached pages, the first page of which is captioned "VERSION WITH MARKINGS TO SHOW CHANGES MADE".

To the extent necessary, Applicants petition for an extension of time under 37 CFR § 1.136. Please charge any shortage in fees due in connection with the filing of this paper, including extension of time fees, to the Deposit Account No. 01-2135 (Case No. 501.36931X00) and please credit any excess fees to such Deposit Account.

Respectfully submitted,

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE CLAIMS

Please amend the claims presently in the application as follows:

1. (Twice Amended) A semiconductor device with a multilayered structure comprising a copper film interconnect formed on one primary surface of a semiconductor substrate, and a neighboring film formed in contact with said copper film interconnect, wherein said neighboring film [is formed of] <u>includes</u> a ruthenium film which substantially prevents voids due to electromigration of copper of the copper film, and said copper film interconnect has a multilayered structure comprising a copper film as formed through sputtering and a copper film as formed through plating.

2. (Twice Amended) A semiconductor device with a multilayered structure comprising a copper film interconnect formed on one primary surface of a semiconductor substrate, and a neighboring film formed in contact with said copper film interconnect, wherein said neighboring film [is formed of] <u>includes</u> a ruthenium film which substantially prevents voids due to electromigration of copper of the copper film, and said copper film interconnect has a multilayered

structure comprising a copper film as formed through physical vapor deposition and a copper film as formed through chemical vapor deposition.

4. (Twice Amended) A semiconductor device with a structure comprising a copper film interconnect formed on one primary surface of a semiconductor substrate, and a plug formed in contact with said copper film interconnect, wherein said plug [is formed of] includes at least one film selected from the group consisting of a rhodium film, a ruthenium film, an iridium film, an osmium film and a platinum film, which substantially prevents voids due to electromigration of copper of the copper film, and at least one of said copper film interconnect and said plug contains a layer as formed through physical vapor deposition.

6. (Twice Amended) A semiconductor device with a structure comprising a copper film interconnect formed on one primary surface of a semiconductor substrate, a neighboring film formed in contact with said copper film interconnect, a plug formed in contact with said neighboring film, and a diffusion barrier formed in contact with said plug and said neighboring film, wherein said neighboring film [is formed of] includes ruthenium film, said plug is formed of a ruthenium film, said diffusion barrier is formed of a titanium nitride film, and at least one of said copper film interconnect and said

neighboring film is a film formed through sputtering, wherein the neighboring film and the plug substantially prevent voids due to electromigration of the copper or platinum of the copper or platinum film.

9. (Twice Amended) A semiconductor device having a layered interconnection structure including a copper film or a platinum film formed overlying a surface of a semiconductor substrate, wherein the layered interconnection structure includes the copper or platinum film and a neighboring film adjacent the copper or platinum film, the neighboring film [being made of] <u>including</u> a material selected from a first group consisting of rhodium, ruthenium, iridium, osmium and platinum when the layered interconnection structure includes a copper film and the neighboring film [is made of] <u>including</u> a material selected from a second group consisting of rhodium, ruthenium, iridium and osmium when the layered interconnection structure includes a platinum film, at least one of (a) the copper or platinum film and (b) the neighboring film being a film made by physical vapor deposition, the device further comprising a diffusion barrier layer, said neighboring film being sandwiched between said copper or platinum film and said diffusion barrier layer, wherein the neighboring film substantially prevents voids due to electromigration of the copper or platinum of the copper or platinum film.